

A contribution to the Ciliata (Protozoa) fauna of chernozem soils

by

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Abstract: Protozoological studies have been carried out in a high quality chernozem soil located in the centre of the Great Hungarian Plain. In the samples 45 Ciliata species have been recorded belonging to 36 genera. The majority of species found are cosmopolitan, with broad ecological tolerance spectrum and they are also known from small water bodies. The number of species and individuals is decreasing step by step parallel with the depth. The highest value of them was found in the 10–20 cm layers, there were no active Ciliata in the 80 cm one, while even cysts were not found in layers deeper than 100 cm. The majority of species found belong to classes Kinetofragminophora and Polyhymenophora with same proportion (46.7%/47.1%). Within Kinetofragminophora Hymenostomata were predominant (almost 24%). Of Polyhymenophora 46.4% were Hypotrichida. The estimated biomass of Ciliata (based on the cultivated numbers of individuals) has been found to be 24 kg/ha in the 0–10 cm layer, while in the 10–20 cm one 42 kg/ha.

Keywords: chernozem soils, Ciliata fauna, biomass, ecology

Introduction

The function and importance of the microfauna (Protozoa: Ciliata) of soils has several aspects. They contribute to the N-fixation of Azotobacter species, decomposition of cellulose (Varga 1934), the growth of juvenile plants (Gellért 1958, Nikoljuk 1956, 1963) and they also increase the crop capacity of fields.

By the products of their metabolism and their biomass they influence bacteria populations and they can make away with pathogen bacteria as well (Varga 1934). Despite of their various and mostly useful activities the microfaunistical (Protozoa, Ciliata) research is falling into the background abroad too (Foissner 1998, see also its references), but in Hungary it is especially neglected. Unfortunately there is not much information available on the Ciliata fauna of the high quality chernozem soils of Hungary either (Horváth 1942–43, 1950, Biczók 1953, 1955, 1956, 1958).

The cultivated soils (e.g. chernozem) are usually richer in Protozoa than other (forest, alkaline, sandy) soils (Fehér & Varga 1929, Nikoljuk 1963). The method of cultivation can disturb the balance of the microfauna (Bonnet 1964). There are diverse communities in soils rich in humous (Bamforth 1973, 1977). It is obvious that these organisms are the most active along the roots, in the so-called rhizosphere (Bamforth 1976, Biczók 1953, 1955 Buitkamp 1977a-b, Gellért 1958, Nikoljuk 1968, Varga 1958, Darbshire & Greaves 1967).

In this study results of the research on the Ciliata fauna of chernozem soils developed in one of the best croplands of the Great Hungarian Plain (Hajdúszoboszló, Eastern Hungary) are given.

Materials and methods

Sampling was carried out in a high productivity chernozem soil, located 15 km to the south of the main road no. 33 between Hajdúszoboszló and Nagyhegyes settlements. Samples were taken from a dug soil profile from layers of 0–10, 10–20, 20–40, 40–60, 60–80 and 80–100 cm with three replications. After a careful mixing of the sub-samples taken from the same depth they (altogether about 1 kg each) were carried to the laboratory in sterile boxes. The homogenised samples were dried on room-temperature for 8–10 days.

During the quantitative analysis of soil samples the culture-dilution method was used. Our method is based on the dilution technique of Varga Telegdy-Kováts (1953), and also that of Singh (1955) with certain modifications, but incorporates several elements of modifications introduced by Brunberg-Nielsen (1968) and Buitkamp (1979). In our opinion this method can be successfully used for the biological analysis of all soil types.

In the course of the quantitative analysis of soil samples the culture method has been modified, by which the starting mass of the dry soil used was increased to 5×10 g (Buitkamp 1979, Foissner 1981, used 8×3 g soil). To the sub-samples 40–40 ml of a 1:5, Protozoon-free soil extractum was added respectively, by which the drastic destroying influence of distilled water can be eliminated. After a careful shaking of samples a dilution series of 8 (1/5–1/640) samples was made, from each of them 10 repetitions were used. One ml suspension was taken for the repetitions, which were injected into plankton tubes containing non-nutrient agar.

During the analysis the volume of the samples processed has been increased from 0.05 ml to 1 ml. These modifications increased significantly the objectivity of the statistical method used, and errors deriving from the aggregated appearance of cysts could be avoided (Gellért 1957, Stout 1962). In this way we tried to avoid errors deriving from random sampling. From each sample 5×80 cultures were set up. Culture tubes were incubated on 21 °C for 6 days (Buitkamp 1979). Processing of data was based on the VIII/2. Table of Fisher & Yates (1963) and on the formula (ind/g) of Brunberg-Nielsen (1968).

Foissner (1987) has published his widely used method for the same purpose in 1987, which is accepted, but our studies were started earlier with another processing method. In order to keep the comparability of our data we have consequently applied the above described method during the long term studies.

After heat treatment — on 58 °C for 45 minutes — the number of cysts was determined from the soil samples, making the determination of the actual number of species and individuals possible.

For the qualitative analysis of the samples cultures were set up in every case (Foissner 1987). 50 g of the air-dry soil sample was put into a crystallizing cup in a step-like pattern. To wet the soil samples Protozoon-free, 1:5 soil extractum was used. Samples were examined on days 2, 4, 6, 10, 14 and 21 and the appearing species were recorded on each occasion.

In order to support the identification of species, the wet silvering method of Klein (1926), the core staining method of Feulgen, the silvering method of Chatton & Lwoff (1936) and the protargol method modified by Wilbert (1975) were used.

The estimated biomass of Ciliata in the soils was calculated by the formula of Pussard (1967, 1971) and given in g/ha. The average mass of solonetz soils was considered to be 1.45 g/cm³. Volume of Ciliata has been calculated by the Simpson-formula (Czoric 1968) and using the method of Buitkamp (1979 and also pers. comm.). The body of the organisms has been compared to simple geometric bodies. The density of the protoplasm has been considered to be 1.

Identification was based on studies by Borror (1972), Buitkamp (1977a, b), Buitkamp Wilbert (1974), Foissner (1979, 1981a, b, 1984), Kahl (1930–1935), Hemberger (1982) and Stiller (1971, 1974). The nomenclature of Ciliata follows Corliss (1979).

Results

45 Ciliata species belonging to 36 genera were found in the chernozem soils with a 1.32 species/genus ratio (Table 1). The majority of species are cosmopolitan, and can be found in surface waters as well. Species most frequently found in the samples are *Colpoda cucullus*, *C. inflata*, *C. steinii*, *Spathidium muscicola*, *Amphisiella milnei*, *Gonostomum affine*, *Uroleptus halseyi*, *Tachisoma pellionella*, *Aspidisca cicada*, *Euplotes muscicola*.

Table 1. List, taxonomic position, abundance, food requirements of Ciliata species occurring in chernozem soils.
+: rare, ++: frequent, +++: very frequent; A: alga, Ba: bacteria C: Ciliata, D: detritus, Fl: Flagellata

Species name	Abundance	Food
KINETOFRAGMINOPHORA		
GYMNOSTOMATA		
PROSTOMATIDA		
<i>Holophrya</i> sp.	+	
HAPTORIDA		
<i>Enchelyodon elegans</i> (Kahl)	+	Ba
<i>Enchelys gasterosteus</i> (Kahl)	+	Ba, Fl
<i>Bryophyllum</i> sp.	+	
<i>Spathidium amphoriphorme</i> (Greef-Penard) Buitk.	++	Ba, C
<i>Spathidium muscicola</i> (Kahl)	++	Ba, C
<i>Spathidium spathula</i> (O.F. Müller)	+++	Ba, C, Fl
<i>Spathidium terricolum</i> (Biczók)	++	Ba, C,
FIPLEUROSOMATIDA		
<i>Litonotus lamella</i> (Ehrb.- Schew.)	++	C, Fl
<i>Loxophyllum</i> sp.	+	
VESTIBULIFERA		
COLPODIDA		
<i>Colpoda cucullus</i> (O.F. Müller)	+++	Ba, D
<i>Colpoda inflata</i> (Stokes)	+++	Ba, D
<i>Colpoda steinii</i> (Maupas)	+++	Ba
<i>Platyophrya angusta</i> (Kahl)	++	A, Fl
<i>Cyrtelophosis elongata</i> (Schewiakoff)	+	
AHYPOSTOMATA		
<i>Drepanomonas revoluta</i> (Penard)	+	
Ba <i>Microthorax simulans</i> (Kahl)	++	Ba, D
CYRTOPHORIDA		
<i>Trithigmostoma</i> sp.	++	
OLIGOHYMENOPHORA		
HYMENOSTOMATA		
HYMENOSTOMATIDA		
<i>Colpodinium caudatum</i> (Wilbert)	++	Ba, D, Fl
<i>Colpidium colpoda</i> (Ehrb., Stein)	++	A, Ba, Fl, D
<i>Tetrahymena rostrata</i> (Kahl, Corliss)	+	A, Ba, Fl
<i>Frontonia parvula</i> (Penard)	++	Ba, C
SCUTICICLIATIDA		
<i>Cyclidium glaucoma</i> (O.F. Müller)	+	A, Ba
PERITRICHIA		
PERITRICHIDA		
<i>Vorticella microstoma</i> (Ehrb.)	++	Ba
POLYHYMENOPHORA		
SPIROTRICHA		
HETEROTRICHIDA		
<i>Blepharisma steinii</i> (Kahl)	+	A, Ba

Table 1. contd

Species name	Abundance	Food
OLYGOTRICHIDA		
<i>Halteria grandinella</i> (O.F. Müller)	++	A, Ba
HYPOTRICHIDA		
<i>Kahliella acrobates</i> (Horváth)	++	Ba, D
<i>Hemicyclostyla</i> sp.	+	
<i>Amphisiella milnei</i> (Kahl)	++	Ba, D
<i>Amphisiella terricola</i> (Gellért)	++	Ba, Fl, D
<i>Gonostomum affine</i> (Stein)	+++	Ba
<i>Holosticha manca plurinucleata</i> (Gellért)	++	Ba, D
<i>Holosticha violacea</i> (Kahl)	+++	Ba
<i>Keronopsis algivora</i> (Gellért)	+	A, C
<i>Uroleptus halseyi</i> (Calkins)	+++	Ba, D
<i>Uroleptus humicola</i> (Gellért)	+	Ba
<i>Uroleptus musculus</i> (Kahl, Foissner)	++	Ba
<i>Histiculus muscorum</i> (Kahl)	+	A, Ba
<i>Opistotricha procera</i> (Kahl)	+	Ba
<i>Oxytricha setigera</i> (Stokes)	++	Ba
<i>Steinia</i> sp.	+	
<i>Stylonychia mytilus</i> (Ehrb.)	++	Ba, Fl
<i>Tachysoma terricola</i> (Hemberger)	+++	Ba, Fl
<i>Aspidisca cicada</i> (Müller)	+++	Ba
<i>Euplotes muscicola</i> (Kahl)	++	Ba, D

In the 0–10 cm layer of chernozem soils as a consequence of exposition, drying, influence of chemicals and radiation the number of individuals is lower by 30–50% than in the 10–20 cm one, where the more stable humidity, the more favourable water-air ratio, the better food supply and the existence of the rhizosphere results in a higher number of species and individuals. In deeper layers the number of individuals is decreasing. We have found no active Ciliata in the 80 cm one, while even cysts were not found in layers deeper than 100 cm. This data show that the Ciliata — similarly to other organisms — inhabit mainly the cultivated layer (0–60 cm). This can be explained by the decrease of the pore volumes, increase of the colloid content and the airless conditions of the lower layers (Table 2).

Table 2. Changes of main features of Ciliata fauna in a chernozem soil

Soil layer (cm) Parameter	0–10	0–20	20–40	40–60	60–80	80–100	100–120
Cultivated number of ind. 1000/kg	1.324	2.206	405	138	18.6	2.7	–
Cultivated number of species	32	38	18	8	5	3	–
Number of cysts	1.100	1.700	298	99.7	1.8	2.7	–
Biomass kg/ha	24.4	42.4	5.6	1.2	0.2	?	–

In the 0–10 cm layer 10 species were found, while 14 in the 10–30 cm one. In the deeper layers the number of species decreases. In the 60–80 cm layer only 3 species (*Colpoda cucullus*, *C. steinii*, *Tachysoma pellionella*) could be found or cultivated. In case of alkaline soils (e.g. crusted meadow solonetz) often no active Ciliata occurred in the 10–30 cm layer!

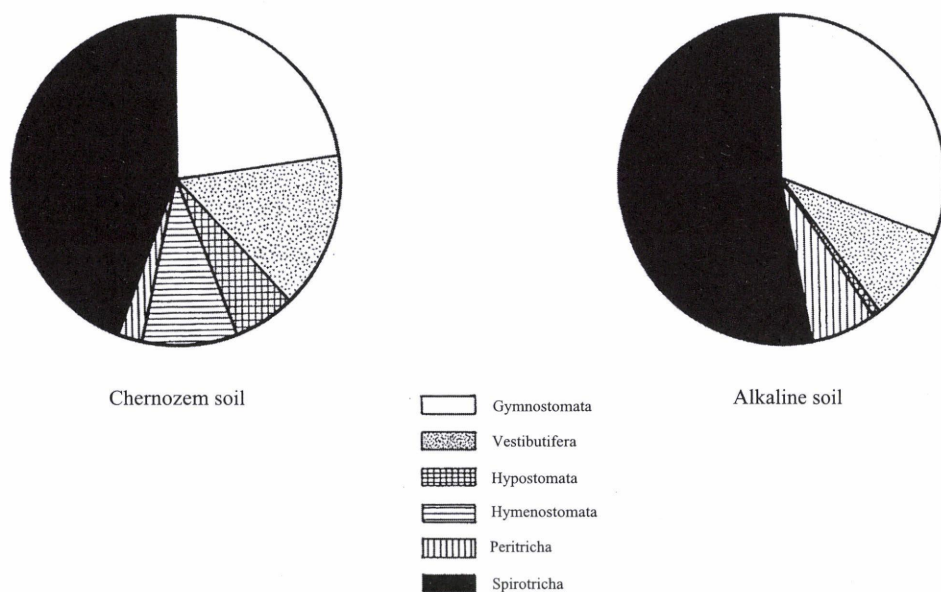


Fig. 1. Changes in the dominance of systematical classes of ciliates

Analysing of the dominance of higher taxonomic groups it turns out that Kinetofragminophora and Polyhymenophora species are present with same proportion (Table 3., Fig. 1), Olygohymenophora represent only 12%.

It is remarkable that Polyhymenophora were represented mainly by Hypotrichida, which means that they give almost 46% of the Ciliata fauna of chernozem soils. In alkaline soils 54–75% of the Ciliata fauna belongs to Hypotrichida. This phenomenon is obviously due to the thinness of capillars and water films developing in them, thus Ciliata are not able to establish and move on the surface of the granules (Fig. 1).

According to our calculations the estimated biomass of Ciliata (based on the cultivated numbers of individuals) is 24 kg/ha in the 0–10 cm layer, while in the 10–20 cm one 42 kg/ha. These data show that the biomass represented by Ciliata communities is a significant contribution to the pool of organic materials of chernozem soils, and their function in the food chain is also of a high importance (Table 2).

Some representatives of the microfauna (Flagellata, Amoeba) are active even in small (11–18 volume %) water content. Ciliata species usually encyst at 13 volume %. According to our observations — in contrary with the opinion of Bonnet (1964) and Horváth (1950) — in the soils, including chernozem ones, the number of individuals of Ciliata is increasing parallel with the increasing water-supply. Thus depending upon the changes in the water-supply there can be even more reproduction peaks and increases in the abundance. Within the vegetation period, based on our experiences the activation of Protozoa in chernozem soils — referred to a given unit of time — is more intensive than in alkaline soils. This can be explained by the different chemical and physical characteristics of the soils concerned, and also by the differences in the amount of the available, biologically accessible nutrients.

Table 3. Dominance relations of the higher taxonomic groups of Ciliata in the different soil types

Biotope	Author	Number of species	Kinetofragm.	Gymnost	Vestibuliphera	Hypostomata	Taxonomic group dominance in %					
							Oligohym. ph.	Hymenostomata	Peritricha	Polyhym. ph	Spirotricha	Hypotricha
Glocknergebiet (small water)	Foissner (1980)	194	44.8				17.5		16.0	21.7		
Glocknergebiet (soil)	Foissner (1981a)	81	50.6				9.9		8.6	30.9		
10 soil types (Italian)	Grandori & Grandori (1934)	101	36.6				23.8		5.9	33.7		
cattle pasture	Buitkamp (1977a)	26	53.7				7.9		3.8	34.6		
Savanna. Lamto	Buitkamp (1977b)	33	60.6				9.1		3.0	27.3		
gallery forest soil	Buitkamp (1977a)	22	50.0				13.7		4.5	31.8		
humus under lichen	Gellért (1956)	32	59.4				6.2		0.0	34.4		
humus under mass	Gellért (1956)	35	42.9				8.7		0.0	48.4		
3forest soils	Gellért (1957)	33	48.5				18.2		3.0	30.3		
litter of forest	Varga (1958b)	27	40.7				25.9		11.1	22.3		
litter of forest	Varga (1960)	22	40.8				22.7		4.5	31.8		
forest soil	Rosa (1956)	29	44.9				6.9		13.6	34.6		
chernozem	Szabó (1991b)	49	46.7	24.4	16.2	6.1	12.2	10.2	2.0	47.1	47.1	46.4
solonetz (deep layer)	Szabó (1991a)	22	39.7	30.2	9.0	0.5	6.4	0.0	6.4	53.9	53.9	50.9
solonetz (crusted) 0.5 cm	Szabó (1991a)	10	31.6	25.6	6.0	0.0	0.0	0.0	0.0	68.4	68.4	68.0
solonetz (crusted) 5-10 cm	Szabó (1991a)	6	25.1	4.0	0.0	0.0	0.0	0.0	0.0	74.9	74.9	72.0

Summary

Research of ciliates of chernozem soils is neglected in Hungary, but in international references as well. This study tries to fill this gap to a certain extent. According to the results of our research carried out in the centre of the Great Hungarian Plain the Ciliata fauna of chernozem soils is rich in species, their diversity is high (45 species, 36 genera). The majority of the species found is cosmopolitan, a part of them is known also from surface water bodies (hydrobiont edaphon).

It is remarkable that in the upper (0–10 cm) layer there are less species than in the 10–20 cm one, probably because of the different ecological circumstances. In the deepest layers active Ciliata has not been recorded. Major part of the species found belongs to Hypotrichida. The estimated biomass based on the numbers of individuals is 24 kg/ha in the 0–10 cm layer, while 42 kg/ha in the 10–20 cm one. This is an evidence for the statement that organic matter represented by Ciliata is significant in these soils.

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